Accessible Images in Computer Science Journals

Bruno Splendiani, Mireia Ribera

Universidad de Barcelona (UB), University of Barcelona, Library and Information Science Faculty, Library and Information Science Department, Melcior de Palau, 140, 08014 Barcelona, Spain

Abstract

Visual content in computer science academic papers is a critical information source, but it presents specific barriers to full readability by people with visual impairments. We aimed to assess current image publishing practices, policies and submission guidelines related to accessibility in a sample of ten highly cited computer science journals. We determined whether the journals claimed to follow an accessibility policy and we reviewed their submission policy and their guidelines related to the visual content, comparing them with good accessibility practices; we manually checked the application of the accessibility policy in one article for each journal. The evaluation shows that the actual practices of image submission in highly cited computer science journals do not fulfill basic recommendations on accessibility. Images within the analyzed articles lack alternative descriptions, even in the case of journals claiming to follow an accessibility policy. Incoherencies between the technical suggestions of image submission and their application in published papers also emerged. Consequently, the visual information of scientific articles is not accessible to people with visual disabilities.

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Keywords: Accessibility, accessible images, electronic publishing, accessibility policies, image alternative text, image description

Corresponding author. Tel.: +34 93 40 34017; fax: +34 93 403 5772.
E-mail address: splendiani@ub.edu
1. Introduction

Persons with disabilities are underrepresented in the science and engineering workforce compared with the population as a whole [1] [2]. In postsecondary education, though computer science is “a popular major choice for high school students with disabilities planning on going to college”[3], the blind and visually impaired community is significantly underrepresented in this discipline [4][5][6]. Successful students and professionals in this community are “predominantly self-taught and have often overcome significant technical and practical barriers” [7], mainly inaccessible course projects and materials. Blind students in STEM fields (a broader definition that includes Computer Science) face several barriers that discourage access to a computer science career. One of the most important is accessing visual resources, as “many STEM subjects rely heavily on visual resources such as graphs, diagrams and charts, which can be inaccessible to blind/partially sighted students unless presented in an alternative format” [8]. Another challenge for students with visual disabilities is the understanding of visual concepts: “the comprehension of ideas that cannot be easily explained in words or through 2D images” [8].

The accessibility discipline defines design principles to make visual content perceivable, understandable and operable by readers despite their impairments and regardless of the technology (user agents and assistive technologies) used by them. A wide range of barriers in reading and learning are experienced by different reader profiles, such as blind/low-vision/color-blind people, people with cognitive disabilities and people with photosensitive epilepsy. These barriers can be overcome by alternative representations to images, including textual descriptions, large printed images, tactile graphics, haptic images and image-to-sound rendering.

In particular, the use of appropriate text alternatives to non-text content is a basic recommendation proposed by the Web Content Accessibility Guidelines WCAG 1.0 and WCAG 2.0 [9]. Many institutions have suggested guidelines on how to make effective image description. Among them, the biggest effort to formalize the praxis of image description into guidelines has been carried out by the Digital Image and Graphic Resources for Accessible Material Center [10] and by the National Center for Accessible Media [11], the last being a global effort to make information embedded in STEM images accessible. The aim of the EDITEUR project [12] is to make digital publications accessible by providing guidelines that include a specific section dedicated to the preparation and editing of accessible images. They frame the description of images in the editorial process and identify alternative text creation as a specific task in the digital publications workflow.

The inclusion of visual information in academic research papers is a widespread practice. However, as noted by Gardner at al. [13], “Very little scientific literature is fully understandable because mathematical formulas and critical graphical information is presently not directly accessible by any non-visual means”. In the scientific community, the most common way to access scientific research is by reading papers in scientific journals, mainly offered in HTML and PDF formats.

Accessibility to the visual content conveyed by images in scientific articles should be guaranteed by providing text alternatives to them. The mechanism to provide alternative textual representations to an image embedded in a scientific paper is a specific markup such as the alt attribute in the img element of HTML, which provides a short and essential description of the image, or the alternate text attribute in PDF with the same function. PDF also allows the inclusion of the actual text attribute, which replicates the text included as an image in textual form. However, the function of the text alternative can be accomplished by any textual description within the context of the paper (such as an image caption, surrounding/adjacent text and other mentions of the image), on the condition that it refers openly to the image and is accessible by assistive technologies.

The accessibility of scientific papers in general and the application of proper text-based alternative descriptions to images in particular is an important topic in computer science research. A great amount of scientific literature related to accessibility is published by computer science journals. According to Wentz et al. [14], computer science is an accessibility-related field and researchers in this area “could support a culture of online accessibility by producing more research […] to support the development of accessible products”. When computer science researchers publish work in accessible formats, they not only play an active role in digital accessibility research but also respect the principles of emancipatory research recommended by some editors, “which require researchers to make their findings available for the benefit of the disabled people’s civil rights movement”[15].
From the point of view of publishers, it is important to make publications accessible in order to fulfill the accessibility regulations (included in legislation in many countries, such as Section 508 in USA) and to comply with their social responsibility. A correctly applied image alternative text also has a parallel advantage in image retrieval, as textual description of images improves the retrieval of the images using search engines [16].

Apart from the importance of making computer science journals accessible to researchers with disabilities and including accessibility policies in computer science journals, this article highlights the need for guidelines to standardize the submission of images with scientific papers. Standard submission guidelines according to international standards have been adopted by academic journals in specific research areas, such as the Uniform Requirements for Manuscripts Submitted to Biomedical Journals [17] for medical publications. Other guidelines include the ISO 80000 International standard, which is a style guide for scientific documents on the use of physical quantities and units of measurement, including mathematical signs and symbols to be used in technology. Templates for article submission are offered by some publishers (such as the Lecture Notes in Computer Science) and are widespread in many conferences, but no shared standard is currently available for manuscript submission to computer science journals.

2. Research method

Ten computer science journals with the highest impact factor according to the ranking of the Journal Citation Report (Science Edition 2011, 23 April 2013) were identified. An extra journal, the International Journal of Computer Vision, was added to the set of journals due to subscription limitations to one of the initially selected journals (the International Journal of Neural Systems). The full list of journals selected in our study is provided in Table 1. The journals are ordered according to the impact factor as it was found in the Journal Citation Report (Science Edition 2012).

Table 1. List of computer science journals selected

<table>
<thead>
<tr>
<th>Journal</th>
<th>ISI JCR Subject(s)</th>
<th>Impact Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEEE Communications Surveys and Tutorials</td>
<td>Computer Science, Information Systems / Telecommunications</td>
<td>6.311</td>
</tr>
<tr>
<td>IEEE Transactions on Pattern Analysis and Machine Intelligence</td>
<td>Computer Science, Artificial Intelligence / Engineering, Electrical &amp; Electronic</td>
<td>4.908</td>
</tr>
<tr>
<td>ACM Computing Survey</td>
<td>Computer Science, Theory &amp; Methods</td>
<td>4.529</td>
</tr>
<tr>
<td>MIS Quarterly</td>
<td>Computer Science, Information Systems</td>
<td>4.447</td>
</tr>
<tr>
<td>Medical Image Analysis</td>
<td>Computer Science, Artificial Intelligence / Computer Science, Interdisciplinary Applications / Engineering, Biomedical / Radiology, Nuclear Medicine &amp; Medical Imaging</td>
<td>4.424</td>
</tr>
<tr>
<td>International Journal of Neural Systems</td>
<td>Computer Science, Artificial Intelligence</td>
<td>4.260</td>
</tr>
<tr>
<td>Journal of Statistical Software</td>
<td>Computer Science, Interdisciplinary Applications / Statistics &amp; Probability</td>
<td>4.010</td>
</tr>
<tr>
<td>International Journal of Computer Vision</td>
<td>Computer Science, Artificial Intelligence</td>
<td>3.741</td>
</tr>
</tbody>
</table>

Each journal was analyzed and documented as follows:
1. The accessibility policy of the journal, as stated in the journal policies on the publisher’s website (where available) and specific references to the alternative text descriptions of images in the accessibility policy.

2. The submission policy of the journal, including the guidelines for authors, specific guidelines on how to submit figures and the instructions of textual description related to figures in articles. We focused on recommendations concerning images and their consequences for image-related accessibility issues, such as textual descriptions of image, color and contrast, font type and size of text (and other labels in images), file format, dimensions and resolution of the image.

3. We assessed the application of alternative text to images in the last research article published in 2013 available online and published not later than April 2013. The full list of the articles selected is provided in Table 2. We manually checked the application of text-based alternative descriptions to the images (graphs, visualizations, pictures, etc.) in the body of the article, according to the compliance with guideline 1.1 of the Web Content Accessibility Guidelines 2.0. We performed the analysis of the presence of the alternate text or actual text attributes in the image tag for the images embedded in PDF versions because of the availability of this format for the great majority of the journals selected (ten journals out of eleven). We were not able to obtain a digital copy of an article from the International Journal of Neural Systems, so the paper selected from this journal was excluded from the analysis. We added the article selected from the International Journal of Computer Vision to the final set of papers analyzed.

4. We checked the correspondence between the image in the article and its references in the body text of the article (“callout”). Finally, we analyzed the technical features of the images that could have an effect on the accessibility/readability of the same, as specified in point 2 above (color, contrast, resolution, etc.).

Table 2. List of articles selected from the Computer Science journals for the evaluation of alt text application

<table>
<thead>
<tr>
<th>Journal</th>
<th>Article</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEEE Communications Surveys and Tutorials</td>
<td>A Survey of Defense Mechanisms Against Distributed Denial of Service (DDoS) Flooding Attacks</td>
</tr>
<tr>
<td>IEEE Transactions on Pattern Analysis and Machine Intelligence</td>
<td>A Globally-Variant Locally-Constant Model for Fusion of Labels from Multiple Diverse Experts without Using Reference Labels</td>
</tr>
<tr>
<td>Journal of Chemical Information and Modeling</td>
<td>Enrichment Factor Analyses on G-Protein Coupled Receptors with Known Crystal Structure</td>
</tr>
<tr>
<td>SIAM Journal on Imaging Sciences</td>
<td>Processing Terrain Point Cloud Data</td>
</tr>
<tr>
<td>ACM Computing Survey</td>
<td>The exact online string matching problem: A review of the most recent results</td>
</tr>
<tr>
<td>MIS Quarterly</td>
<td>Bridging the Qualitative-Quantitative Divide: Guidelines for Conducting Mixed Methods Research in Information Systems</td>
</tr>
<tr>
<td>Medical Image Analysis</td>
<td>Efficient and robust model-to-image alignment using 3D scale-invariant features</td>
</tr>
<tr>
<td>IEEE Transactions on Fuzzy Systems</td>
<td>A Vectorization-Optimization-Method-Based Type-2 Fuzzy Neural Network for Noisy Data Classification</td>
</tr>
<tr>
<td>Journal of Statistical Software</td>
<td>animation: An R Package for Creating Animations and Demonstrating Statistical Methods</td>
</tr>
<tr>
<td>International Journal of Computer Vision</td>
<td>Depth from Refraction Using a Transparent Medium with Unknown Pose and Refractive Index</td>
</tr>
</tbody>
</table>

3. Results and discussion

3.1. Accessibility policies

Five journals out of eleven analyzed had an accessibility policy statement either on their website or on the site of their publishers, four of them referring to WCAG 2.0 and one of them to WCAG 1.0. Making an accessibility
policy statement implies a commitment to make the content of the journal accessible to people with disabilities. Only the Accessibility Policy of the *International Journal of Computer Vision* made a specific reference to the application of textual alternatives “in order to give people of all abilities and disabilities access to the content of your figures”, as shown in Table 3.

Table 3. Application of Accessibility Policy and reference to textual alternatives for images in the selected journals

<table>
<thead>
<tr>
<th>Journal</th>
<th>Accessibility Policy</th>
<th>Explicit reference to textual alternatives for the images</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEEE Communications Surveys and Tutorials</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>IEEE Transactions on Pattern Analysis and Machine Intelligence</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Journal of Chemical Information and Modeling</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>SIAM Journal on Imaging Sciences</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>ACM Computing Survey</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>MIS Quarterly</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Medical Image Analysis</td>
<td>yes</td>
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<tr>
<td>International Journal of Neural Systems</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Journal of Statistical Software</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>International Journal of Computer Vision</td>
<td>no</td>
<td>yes</td>
</tr>
</tbody>
</table>

3.2. Image submission policies and accessibility consequences

In this section the submission policies of the journals are reported according to the following:

- The technical requirements for image submission and the recommendations on the textual information related to the image.
- The possible consequences of the requirements on the accessibility/readability of images for readers with special needs.
- The application of the recommendations to the images in the papers analyzed.

All the journal websites offered a section specifying their submission policy for papers, including a sub-section explaining how to submit artwork in papers. No journal declared that it followed any standard guidelines issued by an international committee in the preparation and formatting of manuscripts. Accessibility issues related to images, such as color and contrast, font type and font size of the text of labels, file format, dimensions and resolution of the image, were not mentioned explicitly in the image submission guidelines for authors. The only exception was a reference provided by the *International Journal of Computer Vision* on the use of patterns in addition to colors for conveying information, in order to make color-blind users able to distinguish visual elements. The same journal recommended providing a minimum color contrast ratio between letters and their background.

3.3. Technical requirements in image submission

The first aspect we analyzed in image submission was the technical requirements that can affect their accessibility. For each topic, we highlight possible references to the specific treatment of figures targeting users with special needs.

3.3.1. Image format

All the journal submission guidelines specify recommended formats for image submission. Five journals only accept images embedded in MS Word files and/or PDF converted from LaTeX format. For raster images, five
journals recommended TIFF format, four JPEG, and two PNG. For vector images, the most accepted formats are PS and EPS (six journals). The *Journal of Chemical Information and Modeling* also accepts Adobe Illustrator format. Other accepted formats in two journals are XLS and PPT, but only under specific conditions (e.g. “Only when the graphic was originally drawn in the program, is it acceptable to submit Microsoft Office Documents”). The analysis of the actual image formats used in papers showed a widespread preference for JPEG and GIF format, the latter being mostly used for diagrams, logos and graphical abstracts.

Under accessibility concerns, the formats most suitable for image publication are those which do not lose quality due to compression and retain all information that was created by the capture device, such as TIFF format. The inclusion of images in JPEG, PPT, XLS and DOC is not recommended because it causes a loss of quality. From the point of view of accessibility, vector images are preferred to raster images because they maintain their resolution despite zooming and resizing. EPS and PDF formats can contain scalable vector images and are usually recommended for line art and combinations of photos and labeling. They also support the inclusion of information in the form of metadata and possibly allow searches in the content of the image, including text.

### 3.3.2. Color and contrast of the image

Only the *SIAM Journal on Imaging Sciences* explicitly encouraged the use of color. The *International Journal of Computer Vision* recommended the use of patterns in addition to colors for conveying information in order to allow color-blind users to distinguish visual elements and recommended a minimum color contrast ratio between letters and their background of 4.5:1. This recommendation corresponds to guideline 1.4.3 of WCAG version 2. *IEEE Transactions on Pattern Analysis and Machine Intelligence* suggested “avoiding bright, light, or neon colors for images that will be in print”. We performed an analysis on images in PDF files in order to check whether a minimum color contrast was correctly applied. The results of the Colour Contrast Analyser\(^1\) software show that in four papers one or more images do not have a minimum color contrast.

The proper use of contrast in images allows users with colorblindness to correctly perceive images and improves access to images in poor lighting conditions and on mobile devices with a limited color palette and ones that use grey scales (such as some types of e-reader devices). From the accessibility perspective, it is also recommended not to rely on colors as the only means to differentiate information. For example, colorblind users and readers of black and white printed version of the image would not be able to distinguish the visual elements in Figure 1 in the article of *Journal of Chemical Information and Modeling*.

![Fig 1. Example of a line chart where colors are used as the only means to differentiate information among lines. Source: [18]](http://www.visionaustralia.org/business-and-professionals/digital-access/resources/tools-to-download/colour-contrast-analyser-2-2-for-web-pages (accessed August 28, 2013))

For good readability, it is recommended to use patterns instead of (or in addition to) colors for conveying information, as in Figure 2 in the article of *IEEE Transactions on Pattern Analysis and Machine Intelligence*.

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3.3.3. Image resolution and dimensions

Six journals required a minimum resolution of 300 dots per inch for image submission. In five journals, the resolution requirements depended on the type of image: for example, the preferred resolution for line-art images differed for color and grayscale images and ranged from 300 to 1200 dpi. Among the images extracted from the PDF version of the articles analyzed, only one image in the article of *IEEE Communications Surveys and Tutorials* had a minimum resolution of 600 dpi.

A low resolution could negatively affect access to the image by low-vision readers. Particularly at high levels of magnification, the readability of raster images can be compromised by pixelation. Vector formats could be a solution for avoiding the loss of resolution when images are displayed at high magnification rates of x3 or higher.

The majority of the guidelines required a minimum size for image submission, starting from a minimum final width of approximately 3.3/3.9” for half-page figures and 6.9/8.5” for full-page figures. The stated maximum image height (four journals) ranged from 8.8” to 9.21”. Small dimensions could have negative consequences on the ability of low-vision readers (and in general of all readers) to properly understand the content of the image, especially in the print version of the paper.

3.3.4. Size and name of image file

Four journals provided recommendations on image file naming. All of them suggested including the number that represents the sequential location of the image in the article. *IEEE Communications Surveys and Tutorials* suggested the inclusion of the author’s last name in the file name. *Medical Image Analysis* recommended the inclusion of the file extension in the file name “to enable quick and easy format identification”. The file name is the simplest textual data describing the image. Accurate file naming can provide valuable information to be read by screen readers and retrieved by search engines to identify the content of a figure and establish its importance for retrieval.

File size is inversely proportional to image quality and the balance between the two factors depends on the intended use of the image. If the figure is for publication, limitations on file size could force the author to compress high-quality images, causing a loss of resolution. Only *Medical Image Analysis* specifies a preferred file size (7-10 MB maximum).

3.4. Textual information related to the image

3.4.1. Image legend

The title and the legend (also known as the caption, the brief explanation usually appearing immediately above, beneath, or adjacent to an image) are the most common texts for the content definition and description of a figure. They convey visual information in a textual way and can help blind people to locate the image and access its
content. They can also be useful for interpreting the figures for readers with cognitive impairments or even readers with low visual literacy (people who have limited skills in making meaningful interpretations of visual stimuli). When the legend describes the content of the image properly and provides extensive information on the image, the use of the alt text attribute could be redundant. Only two journals (the *Journal of Statistical Software* and the *International Journal of Computer Vision*) provided suggestions on caption content. The *International Journal of Computer Vision* recommended that authors “identify all elements found in the figure caption; and use boxes, circles, etc., as coordinate points in graphs”. As specified in the section dedicated to the use of color, it is important to avoid referring from the legend to image features only by specifying color or position. People with color blindness, blind people and readers using black and white print versions of the image may not be able to understand information provided in these ways.

3.5. Labeling

Labels such as text, arrows and symbols are features of an image that are directly related to its content. Their function is to tag, point to or indicate a specific part of the figure as the focus of attention. As a source of extra textual information, from the point of view of accessibility, labels can be used as a support for interpreting the images. *IEEE Transactions on Pattern Analysis and Machine Intelligence* and the *International Journal on Computer Vision* suggest providing the labels separated from the figure, in order to make them easier to edit.

For letters and labels, a sans-serif font (Arial or Helvetica) was recommended by five journals. Three journals recommended Times New Roman font (serif), and two suggested Courier (serif). Only five of the papers analyzed had body text and text in figures in sans-serif fonts. To ensure best readability for readers with low vision or cognitive impairments and readers using small screens, sans-serif fonts such as Verdana, Helvetica and Arial are better considered than serif fonts such as Times New Roman or Courier.

The label font size recommended by six guidelines ranged between 7 and 12 pt. Font size is a central accessibility issue for people with low vision and the WCAG 2.0 guidelines encourage the use of a minimum 12 pt size for body text or text in images. Almost all the text in figures in the papers analyzed was found to be smaller than 12 pt size.

Four journals recommended the use of standard units. The application of standard units in scientific publications has a positive effect on the readability of labels and other text associated with images, since it standardizes the conventions in labeling and makes the images comprehensible for the whole community of researchers.

Three guidelines (of *IEEE Communications Surveys and Tutorials*, *IEEE Transactions on Pattern Analysis and Machine Intelligence* and the *International Journal of Neural Systems*) referred to specific treatment for tagging and referencing multi-panel images in legends. Multi-panel images usually have a high density of semantic content and require specific treatment and reference in the legend, in order to specify the localization, order and relations between different images in the same figure. A good accessibility recommendation would be to minimize their use to clearly defined cases.

3.6. Analysis of the application of alternative text

The images contained in the ten articles selected were analyzed in detail to review the actual implementation of textual alternatives to the figures. Specifically, in the analysis of articles we focused on the proper application of the *alternate text* and *actual text* attributes of the image tags (in the PDF version). Our results show that none of the papers analyzed contains images with alternative text descriptions. In Table 4, we summarize the results of the analysis of images issues related to accessibility according to the recommendations provided by journals and their application in papers.

<table>
<thead>
<tr>
<th>Accessibility issue</th>
<th>Recommended by journal</th>
<th>Applied in paper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Format (vectorial formats recommended)</td>
<td>7 journals out of 11</td>
<td>0 papers out of 10</td>
</tr>
</tbody>
</table>
4. Conclusions

Despite the role of images in conveying essential information in computer science publications, the importance of the visual content is underestimated in the publishing process. An accurate process of image submission in computer science journals according to common guidelines assumes critical importance if the journal wishes to ensure access to graphical content for all types of reader, including readers with visual impairments.

This study highlights the current policies in image submission in relation to the effective accessibility/readability of figures and its application in a sample of papers in highly cited computer science journals. The results show that there are currently no common guidelines on image submission among highly cited journals in the computer science area. In more than half of the journals analyzed, these guidelines did not include an accessibility policy and in almost all of the cases they failed to address issues related to image accessibility. Even when the submission guidelines were based on major accessibility guidelines, the image analysis of PDF papers showed that their application was inconsistent in most published papers.

An image submission process based on a shared common set of international guidelines could have a positive effect on the reduction of incoherencies between the guidelines recommended and their actual application in papers, and would reduce reading barriers to visual content by readers with visual impairments and readers in general. As a starting point, we invite scientific publishers to adhere to common basic accessibility guidelines, which would generate parallel advantages in image management, retrieval and sharing. General suggestions based on recognized accessibility guidelines should include the following:

- Accept image formats without loss of quality and allowing the inclusion and preservation of metadata information, such as TIFF or SVG format.
- Implement an automatic check of the minimum level of color contrast (4:5:1) and the minimum resolution (300 dpi) in submitted images.
- Recommend the use of a combination of colors and patterns for providing information in figures. Show the images in black and white to authors to increase their awareness of potential accessibility barriers.
- Recommend a minimum font size (12 pt), sans-serif fonts (such as Verdana, Helvetica and Arial) and the use of standard units for image labels.
- The submission system should promote the inclusion of alternative text. Thus, the article generated would automatically include images with alt text.
- Insert guidelines and examples on how to create alternative descriptions for images, such as the ones developed by the National Center for Accessible Media [11], in the submission system.
In this paper we have identified some limitations in the image submission process of computer science journals. With a view to remedying this situation, we are currently working on a complete set of guidelines for the inclusion of image accessibility criteria in the academic publication process, focusing on specific research fields such as computer science, mathematics, and biology.

Acknowledgements

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